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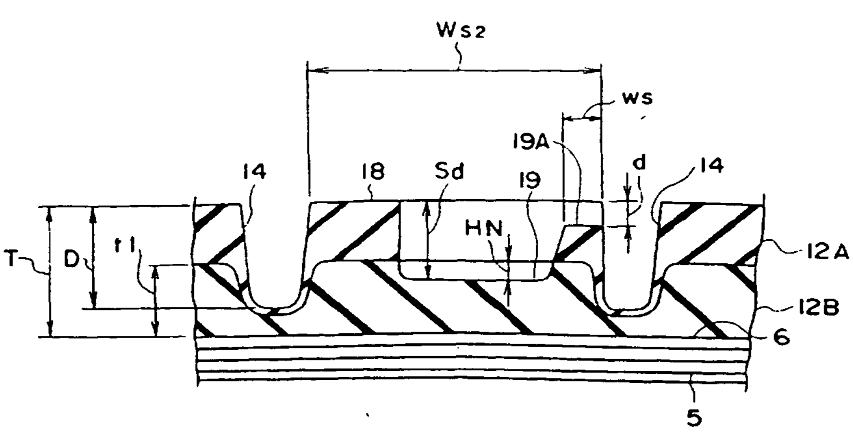
(54) **Pneumatic tyre**

(57) There is provided a pneumatic tire in which a plurality of land portions are formed in a tread road-contacting surface. the total negative ratio N of the road-contacting surface is set in a range from 25% to 65%, and the depth D of each groove is set at 5mm or more. The plurality of land portions bite into a snow-covered surface, and a high tire performance on snow can be achieved. Further, in this pneumatic tire, sipes (the depth Sd of the sipe is given by $D \times \alpha$ ($0.1 < \alpha < 1.0$) which are formed in the land portions to extend inward in the radial direction of the tire allow removal of water between the tire and a snowy or icy road surface and the edges of the sipes allow cutting of the water film, thereby resulting in an improvement of the road contacting performance of the tire. Moreover, in the pneumatic tire, the elongated closed cells provided in the tread rubber serve as a water discharge passage up to the last stages of wear, and therefore, water discharge and removing effects can be constantly obtained efficiently. A protective layer made from resin prevents crushing of the elongated closed cells. Accordingly, even under the application of a heavy load, the water discharge and removal effect can be obtained.

FIG. 3



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the last stages of wear, and the water removal and discharge effect can be constantly obtained without being influenced by the state of wear.

The elongated closed cells are each reinforced by being covered with a protective layer made of resin, and the tire performance on ice and snow can be improved without wear resistance and biased wear characteristics being deteriorated.

Additionally, the protective layer made from resin prevents crushing of the elongated closed cells, and therefore, the water discharge and removal effect can be maintained even under application of a heavy load.

When the total negative ratio N of the road-contacting surface portion is less than 25%, a water removing effect on a wet road surface and an ability to run on a road surface covered with snow cannot be obtained.

On the other hand, when the total negative ratio N of the road-contacting surface portion exceeds 65%, the road contacting surface area of the tire becomes extremely small. For this reason, the force with which the tire grips the road surface decreases and maneuverability is lost.

The total negative ratio N of the road-contacting surface is thus preferably set in the range from 28% to 45%.

Further, when the depth Sd of the sipe is less than 0.1D, the volume of the sipe is not sufficient to remove a water film and a water removal effect cannot be exhibited.

When the depth Sd of the sipe exceeds 1.0D, the rigidity of the tread land portion sharply decreases and the land portion falls flat when a load is applied thereto. For this reason, the road-contacting surface area of the tire markedly decreases and any improved performance effect is lost.

Therefore, it is more preferable that $0.5 < \alpha < 1.0$.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of a pneumatic tire according to an embodiment to which the present invention is applied.

Fig. 2 is a plan view of a tread of the pneumatic tire according to the embodiment of the present invention.

Fig. 3 is an enlarged cross-sectional view of the tread along a sipe.

Fig. 4 is an enlarged plan view of the tread.

Fig. 5 is an enlarged cross-sectional view of the tread.

Fig. 6 is an enlarged cross-sectional view of an outer rubber layer.

Fig. 7 is a perspective view of an elongated resin.

Fig. 8 is an explanatory diagram which illustrates the principle of aligning the directions of the elongated resins.

Figs. 9A to 9D are diagrams which illustrate a process in which an elongated closed cell is formed.

Fig. 10 is a graph which shows the relation between temperature (vulcanizing time) and the viscosities of rubber and resin.

Fig. 11 is an enlarged cross-sectional view of a worn outer rubber layer.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First, a description of a pneumatic tire according to an embodiment of the present invention will be given with reference to Figs. 1 to 11.

As shown in Fig. 1, a pneumatic tire 10 (size: 185/70R14) of the present embodiment has a case 1 and a tread 12 which covers the outer side of a crown 2 of the case 1 in the radial direction of the tire between shoulders 3.

The case 1 has a pair of beads 4, a toroidal carcass 5 formed from a rubber coated cord extending from one bead 4 to the other bead 4, and a publicly-known inextensional belt 6 disposed at the outer side of the carcass 5 in the radial direction of the tire across the region of the crown 2 and extending in the circumferential direction of the tire. Further, a side wall 7 formed from ordinary rubber having excellent elasticity is disposed at the outer side of the case 1 in the axial direction of the tire.

The pneumatic tire 10 according to the present embodiment is a tire for winter use (a so-called studless tire). As shown in Fig. 2, the tread 12 has five circumferential grooves 14 formed thereon, and two ribs 15 formed on both sides of the equatorial plane CL of the tire between a circumferential groove 14 formed on the equatorial plane CL of the tire and circumferential grooves 14 formed on both sides of the above-described circumferential groove 14 and extending along the circumferential direction of the tire.

Further, transverse grooves 16 are formed on both sides of the ribs 15 extending in the transverse direction of the tire (i.e., the direction indicated by arrow B) and a plurality of blocks 18 are thereby formed between the transverse grooves 16 and the circumferential grooves 14.

A plurality of sipes 19 is formed in each of the ribs 15 and the blocks 18 in such a manner as to extend substantially in the transverse direction of the tire.

The pneumatic tire to which the present invention is applied preferably has a cap/base structure. As shown in Fig.

tire performance on ice can be obtained.

Further, the rubber composition for forming the outer rubber layer 12A preferably includes at least one kind of rubber selected from a group consisting of natural rubber and diene-based synthetic rubber.

Diene-based synthetic rubbers include styrenebutadiene copolymer, cis-1,4-polyisoprene, cis-1,4-polybutadiene, and the like.

Among these, cis-1,4-polybutadiene is favorably used in respect of its low glass transition temperature and a large effect by improvement of a tire performance on ice, and polybutadiene having a cis percentage content of 90% or more is particularly preferable.

In order that cells are formed in the outer rubber layer 12A, a foaming agent and foaming auxiliaries are contained in the rubber composition.

Examples of the foaming agent include dinitrosopentamethylene tetraamine (DPT), azodicarbonamido (ADCA), dinitrosopentastyrenetetramine and benzenesuphonylhydrazide derivatives, oxybisbenzenesulphonylhydrazide (OBSH), and the like. Among these, azodicarbonamido (ADCA) is preferable in view of its manufacturing properties.

As the foaming auxiliaries, there are preferably applied urea, zinc stearate, zinc benzenesulfinic acid, zinc white, and the like, which are usually used for manufacturing foamed products.

The foaming agent and the foaming auxiliaries each may contain components other than the aforementioned.

Further, the rubber composition includes, in addition to the above-described rubber components, carbon black, silica, a silane coupling agent, process oil, a vulcanizing agent, a vulcanization accelerator, and the like. Moreover, additives such as an antioxidant, zinc oxide, stearic acid, and an antiozonant, which are in ordinary use in the rubber industry, are also included.

In the refining process (kneading process) of the above-described rubber composition, elongated resins 32 as shown in Fig. 7 are kneaded so as to be uniformly dispersed.

Here, the resin 32 used in the present embodiment is a thermoplastic resin whose viscosity is lower than that of the rubber matrix in the tire vulcanization process.

Generally, the viscosity prior to melting of a resin phase is much higher than the viscosity after crosslinking (Max value) of the rubber matrix. However, once the resin phase is molten, the viscosity thereof decreases sharply. From the beginning to the end of the tire vulcanization process, the viscosity of the rubber matrix increases due to the crosslinking reaction. During this process, the elongated resin phase is molten and the viscosity of the resin phase which has become sharply higher thereby decreases inversely to the viscosity of the rubber matrix (under crosslinking) in a relative manner.

The "rubber matrix" mentioned herein indicates the rubber portion not including the resin 32.

An important condition in order to obtain the elongated closed cells 24 which are entirely reinforced by the protective layer 26 is that, when the resin 32 contained in the rubber is a crystalline polymer, the melting point of the crystalline polymer is set to be lower than or equal to the maximum vulcanizing temperature.

The elongated closed cells 24 reinforced by the protective layer 26 are formed by utilizing a state where the resin 32 is made molten due to the heat generated by the vulcanization so that the viscosity thereof becomes lower than that of the rubber matrix, and gas generated from a foaming agent included in advance in the rubber is diffused or dissolved in the rubber and moves to concentrate in the inner side of the molten resin 32 which has the lowest viscosity in all the rubber.

Accordingly, it is important that, when the resin 32 is a crystalline polymer, the melting point thereof be set at the maximum vulcanizing temperature of the tread portion or less. Moreover, the maximum vulcanizing temperature of the tread portion" mentioned herein indicates the maximum temperature of the tread portion during the period in which a tire is inserted into a mold, is taken out from the mold, and is cooled.

The rubber viscosity is in the range from 30 to 100 at Mooney viscosity.

The melting viscosity of the resin 32 depends on the melting point (in the case of crystalline polymer) and the molecular weight.

It is preferable that the melting point of the resin 32 is lower than the maximum vulcanizing temperature of a rubber to be used. The reason is that, the lower the melting point of the resin 32 is in comparison with the maximum vulcanizing temperature of the rubber, the earlier in the vulcanization process the resin 32 becomes molten, thereby allowing gas generated in the rubber to easily penetrate into the resin 32.

When the melting point of the resin 32 is too close to the maximum vulcanizing temperature of the rubber, the resin 32 is still molten in the last stage of the vulcanization process. At this point in time, the rubber matrix is already subjected to crosslinking with gas being taken therein, and therefore, it is difficult for the gas to penetrate into the molten resin 32 and for the elongated closed cell 24 to thereby be formed.

On the other hand, when the melting point of the resin 32 is excessively low, the resin 32 is molten by the heat given off during the kneading of the rubber and the viscosity of the resin 32 decreases. For this reason, the resins 32 are fused to each other in the kneading stage thereby causing a deterioration of the dispersibility of the resins 32 in the rubber, which is not preferable. Further, when the melting point of the resin 32 is excessively low, the elongated

longitudinal directions of the resins 32 are made uniform in the direction of extrusion, and thereafter, the belt-shaped rubber composition 36 extruded from the nozzle 38 is cut to a desired length and the cut rubber composition 36 can be used as the rubber material of the outer rubber layer 12A.

The extent to which the longitudinal directions of the resins 32 are aligned varies depending on the rate at which the passage cross-sectional area decreases, the extrusion rate, the viscosity of the rubber and the like.

In order that the elongated resins 32 be arranged in a desired direction, i.e., the extruding direction, it is important to control the fluidity of the rubber within a limited temperature range. In other words, by suitably applying a workability improving agent such as oil and liquid polymer to the rubber composition so as to decrease the viscosity of the rubber matrix and thereby improve the fluidity of rubber, the resins 32 can be extruded extremely favorably, even under the constraint of maintaining an extrusion temperature which is the melting point of the elongated resins 32 or less, and the elongated resins 32 can be ideally aligned along the direction of extrusion.

In such a manner that the outer rubber layer 12A in the state of a belt-shaped raw rubber formed from the rubber composition thus obtained is applied onto the inner rubber layer 12B of raw rubber applied in advance to the crown of a green tire case and vulcanization molding is effected therefor in a predetermined mold, at a predetermined temperature, and at a predetermined pressure, the pneumatic tire 10 of the present embodiment can be formed.

In order that the elongated closed cells 24 provided at the inner side of the transverse direction of the tire are oriented in the circumferential direction of the tire and the elongated closed cells 24 provided at an outer side of the transverse direction of the tire are oriented in the transverse direction of the tire, the above-described raw rubber composition is applied to the inner side of the transverse direction of the tire so that the elongated resins 32 are oriented in the circumferential direction of the tire, and the above-described raw rubber composition is applied to the outer side of the transverse direction of the tire so that the elongated resins 32 are oriented in the transverse direction of the tire.

When the raw outer rubber layer 12A is heated in the mold, as shown in Fig. 9A, generation of gas 34 is begun by a foaming agent.

When the raw outer rubber layer 12A is heated to allow melting (or softening) of the resin 32 and the viscosity of the resin 32 becomes lower than that of the rubber matrix (see Fig. 10), as shown in Fig. 9B, the gas 34 generated around the resins 32 moves into the molten resins 32. Finally, air bubbles of the gas 34 moving into the molten resins 32 connect together to form an elongated space and gas generated in a position separated from the resins 32 stays therein.

The outer rubber layer 12A after having been cooled becomes a foamed rubber in which spherical closed cells 22 and elongated closed cells 24 which are each reinforced by the protective layer 26 of the resin 32, whose outer peripheral portion is solidified, are formed (see Figs. 9C and 9D).

[Operation]

A description will be hereinafter given of the operation of the present embodiment.

When the pneumatic tire 10 according to the present embodiment is subjected to a running test, as shown in Fig. 11, concave portions 22A formed by substantially spherical closed cells 22 and groove-shaped concave portions 24A formed by elongated closed cells 24 appear on the road contacting surface of the tread 12.

When the pneumatic tire 10 is subjected to a running test on ice, a water film is generated between the tire and the ice surface due to contact pressure and frictional heat. However, a large number of concave portions 22A and 24A formed on the road contacting surface of the tread 12 allow quick discharge and removal of water (water film) on the road contacting surface. Further, the groove-shaped concave portions 24A appearing on the road contacting surface serve as water discharge passages to remove water on the road contacting surface more efficiently than the spherical closed cells 22.

Since the groove-shaped concave portions 24A are formed in such a manner that the outer peripheral portion thereof is reinforced by the protective layer 26 which is harder than the rubber matrix, the concave portion 24A is not apt to deform even under the application of a heavy load and can constantly maintain high water discharge and removal properties without being affected by a variation of load.

In addition, the pneumatic tire 10 of the present embodiment allows further improvement of the frictional force between the tire and the road surface based on the protective layer 26 exposed to the road contact surface acting to scratch the road surface.

According to the method for manufacturing the pneumatic tire 10 provided by the present embodiment, the elongated resin 32 can be made hollow even under the conditions of a high temperature and high pressure during vulcanization molding and elongated closed cells 24 reinforced by the protective layer 26 which can obtain sufficient water discharge and removal properties can be reliably formed.

Here, in the foamed rubber portion which forms the outer rubber layer 12A, a total expansion ratio Vs comprising the expansion ratio Vsl of the spherical closed cells 22 and the expansion ratio Vs2 of the elongated closed cells 24 combined is desirably set in the range from 3 to 40%, and preferably 5 to 35%. The total expansion ratio Vs of the

ice, traction performance on ice, and feeling on ice were conducted for each of the above tires and the results were compared with one another.

A description will be hereinafter given of the tires in accordance with comparative examples 1, 2 and embodiment 1. The size of each of these tires is 185/70R14.

The tire in accordance with embodiment 1 has the structure described in the above-described embodiment (see Figs. 1 to 6). The tire in accordance with comparative example 1 has the same pattern as that of the tire of embodiment 1, except that the tread rubber has no elongated closed cells 24 and has only spherical closed cells. The tire in accordance with comparative example 2 is formed so that the tread rubber has no elongated closed cells 24 and has spherical closed cells and short fibers of polyester.

Next, other specifications and the test method of each of the tires will be described.

Volume ratio of spherical closed cells to elongated closed cells:

A block piece is cut out from the tire tread and the surface to be observed is cut open by a sharp-edged razor along a direction perpendicular to the circumferential direction of the tire and also along a direction perpendicular to the tread surface. The cut sample was photographed at a magnification of 100 using a scanning electron microscope. The portion to be photographed was set by random sampling. Next, in the photograph of the cut sample, a portion of the spherical closed cells and a portion of the elongated closed cells each having a resin protective layer are separated from each other, respective areas of the two portions of closed cells are measured, and the area ratio between the spherical closed cells and the elongated closed cells in a fixed area is calculated. The above-described measurement is made ten times and an average area ratio is obtained and set as the volume ratio of the spherical closed cells to the elongated closed cells.

Hardness:

The vulcanized rubber composition was measured at 0°C according to JIS K6301.

Average inner diameter of the elongated closed cells:

The total area of the elongated closed cells measured in the foregoing is divided by the number of the observed elongated closed cells, and an average cross-sectional area for each closed cell is thereby obtained. The diameter of the elongated closed cell, assuming that the cross section is completely circular, is calculated by the following formula.

$$\text{Inner diameter of elongated closed cell} = (\text{cross-sectional area for each closed cell} \div \pi)^{0.5} \times 2$$

The above-described measurement is conducted ten times and the average value thereof is determined as the average inner diameter of the elongated closed cells.

L/D:

The ratio, L/D, is the value obtained by dividing the length of short fibers by the inner diameter given by the above measurement. The length of the elongated closed cells may be actually measured by cutting samples for each closed cell, but many errors occur in this measurement. Accordingly, the above-described definition is employed.

Thickness of the resin layer which forms the elongated closed cells:

The cut sample used in the above-described measurement is used and photographed with a scanning electron microscope set at a high magnification which allows measurement of the thickness of the resin, and the thickness is measured at each of four locations on each elongated closed cell. This measurement is conducted for each of 40 elongated closed cells and the average value thereof is set as the thickness of the protective layer of the elongated closed cells.

An on-vehicle test was conducted in such a manner that the tire to be tested, having an internal pressure of 200kPa, was mounted on a 1600cc-type car made in Japan (carrying two passengers). Each test method will be hereinafter described.

TABLE 1 (continued)

		Comparative Example Tire 1	Comparative Example Tire 2	Embodiment
Outer rubber layer	total expansion ratio (%)	26	26	26
	volume ratio between 1st and 2nd closed cells	————	————	55:45
	hardness (degree)	48	50	49
	1st closed cell average hollow diameter(μm)	100	100	120
	2nd closed cell			
	average hollow diameter(μ m)	————	————	190
	L/D	————	————	18
	thickness t of protective layer (μml	————	————	2.9
	resin			thermoplastic
	type	————	polyester	resin
	diameter(μ m)	————	50	22
	length(mm)	————	2.0	2.0
	melting point (°C)	————	255°C	135°C
feeling on snow		100	100	100
braking performance on ice		100	110	120
traction performance on ice		100	110	120
feeling on ice surface		100	110	120

Meanwhile, in Table 1 listed above, the first closed cell and the second closed cell in the vulcanized rubber composition indicate the spherical closed cell and the elongated closed cell, respectively, which are described in the above-described embodiment of the present invention.

cis-1,4-polybutadiene: BR01 manufactured by JSR
carbon black: Asahi Carbon N110
silica: Nipsl AQ manufactured by NIPPON SILICA INDUSTRIAL CO., LTD.
silane coupling agent: Si69 manufactured by DEGUSSA
antioxidant: N- (1,3-dimethylbutyl) -N-phenyl-P-phenylendiamine
vulcanization accelerator: N-cyclohexyl-2-benzothiazyl-1-sulfenamide
foaming agent DPT: Cellular D manufactured by EIWA CHEMICAL INDUSTRIAL CO., LTD.
foaming accelerator (urea-based): Cellupaste K5 manufactured by EIWA CHEMICAL INDUSTRIAL CO., LTD.
thermoplastic resin: PE (polyethylene)

From the test results shown in the above table 1, it is apparent that the tire in accordance with embodiment 1 to which the present invention is applied has a more improved braking performance on ice, traction performance on ice, and feeling on ice than the tires of comparative examples 1 and 2.

As described above, the pneumatic tire of the present invention, having the above-described structure, has an excellent effect that water removal capabilities can be efficiently exhibited without being affected by the running conditions or the state of wear of the tire, and the tire performance on snow and ice can be improved greatly.

FIG. 1

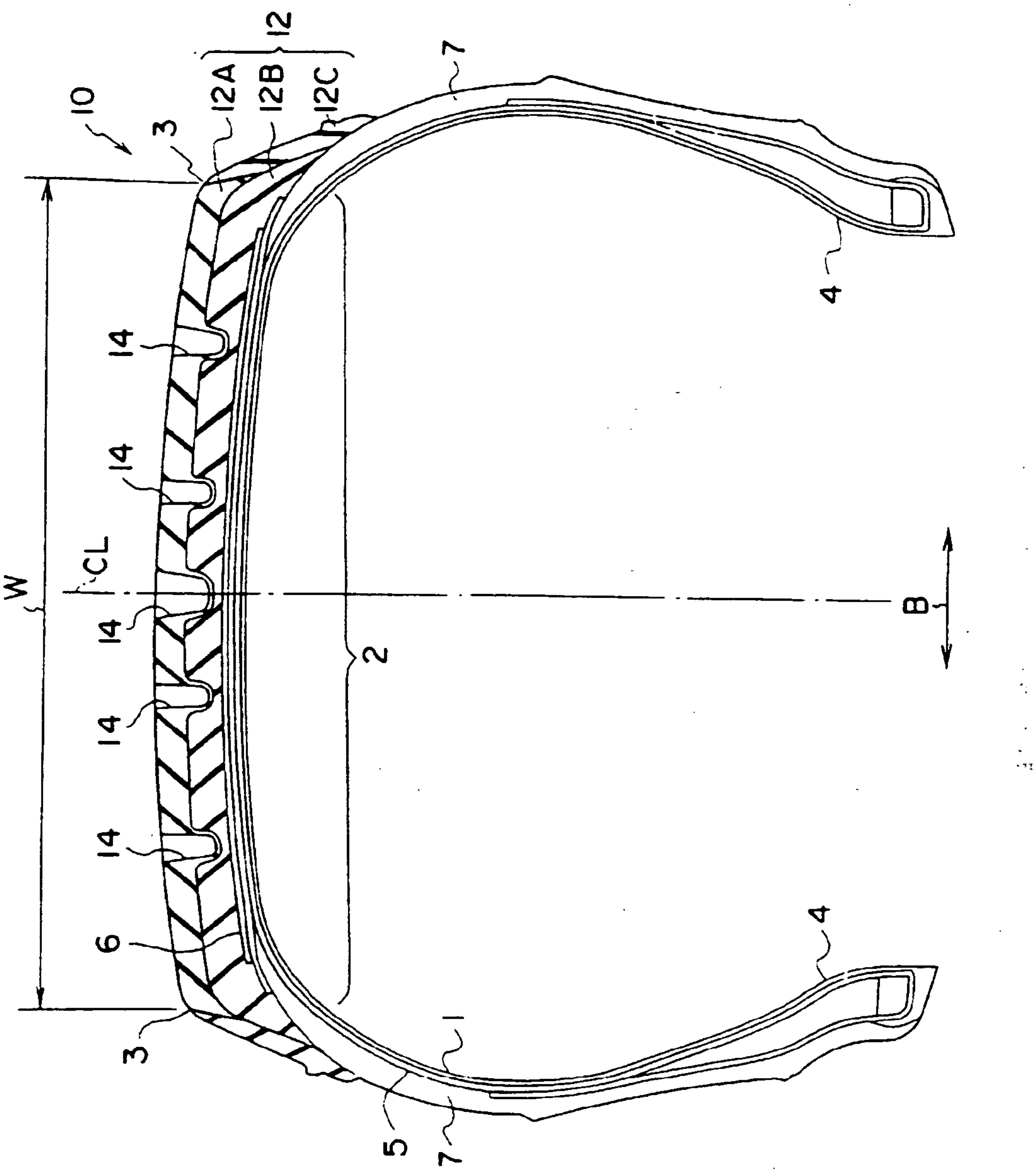


FIG. 3

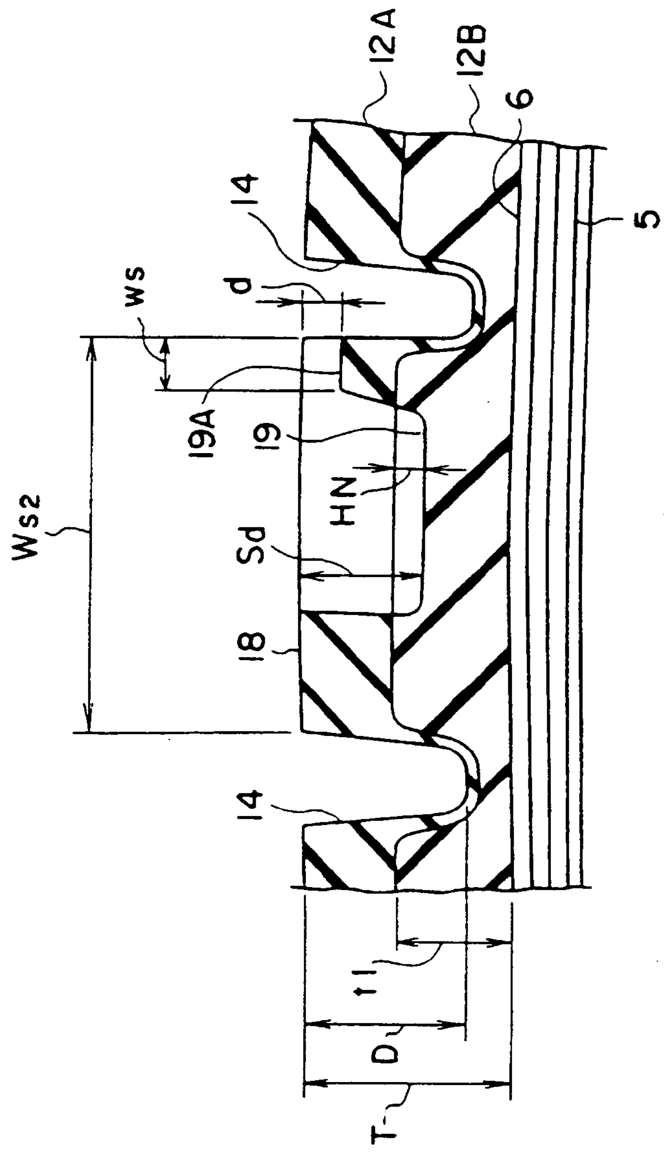


FIG. 5

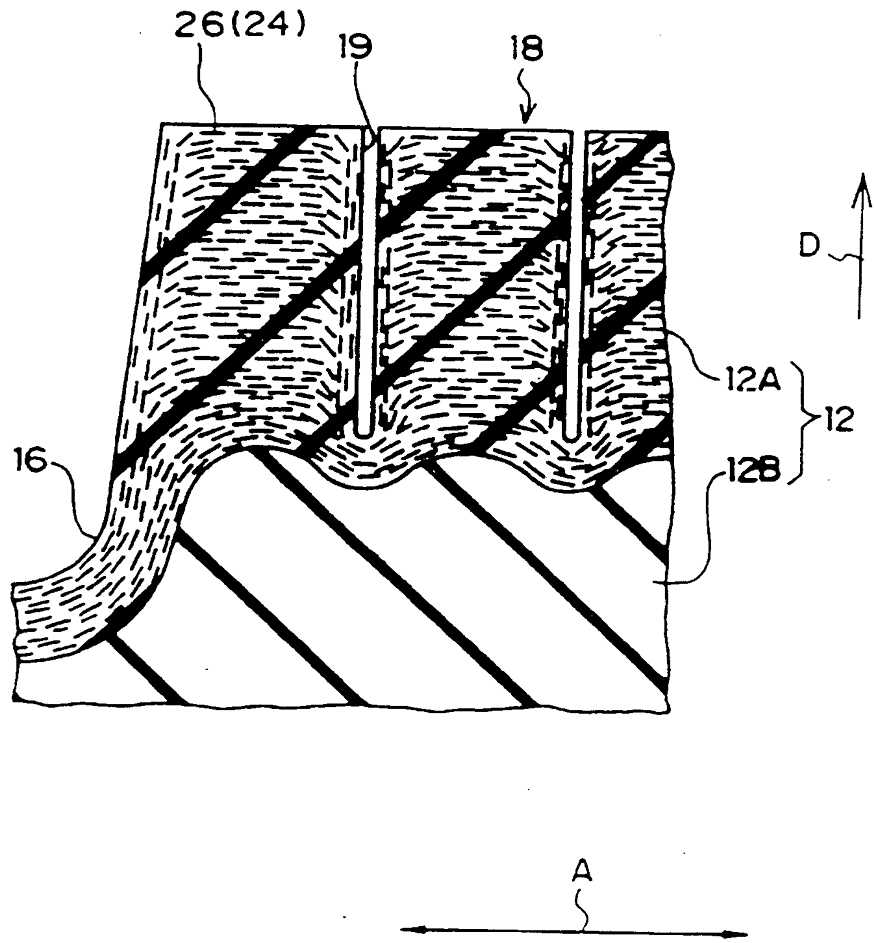


FIG. 7

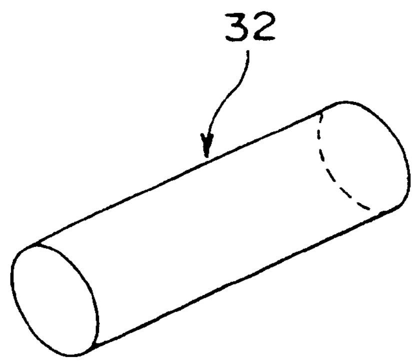


FIG.9A

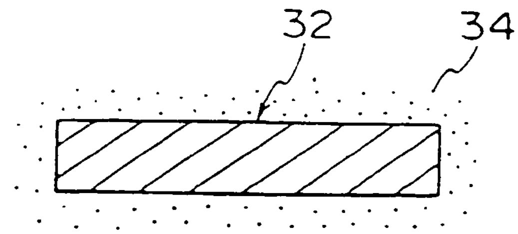


FIG.9B

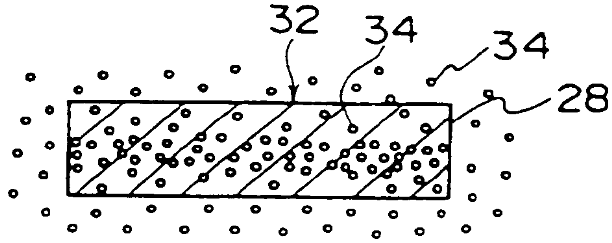


FIG.9C

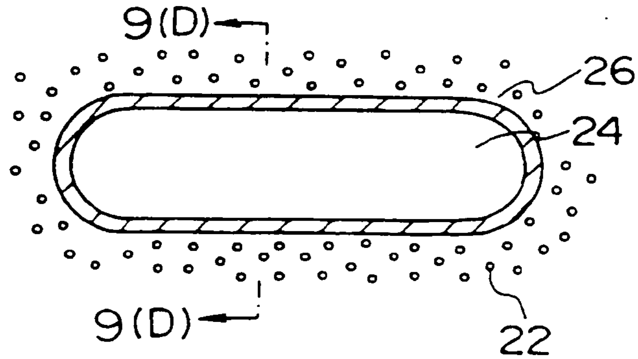
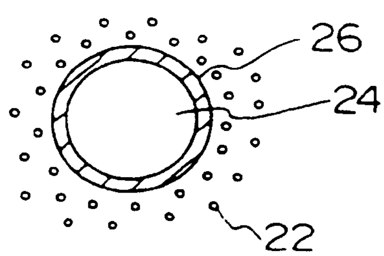


FIG.9D



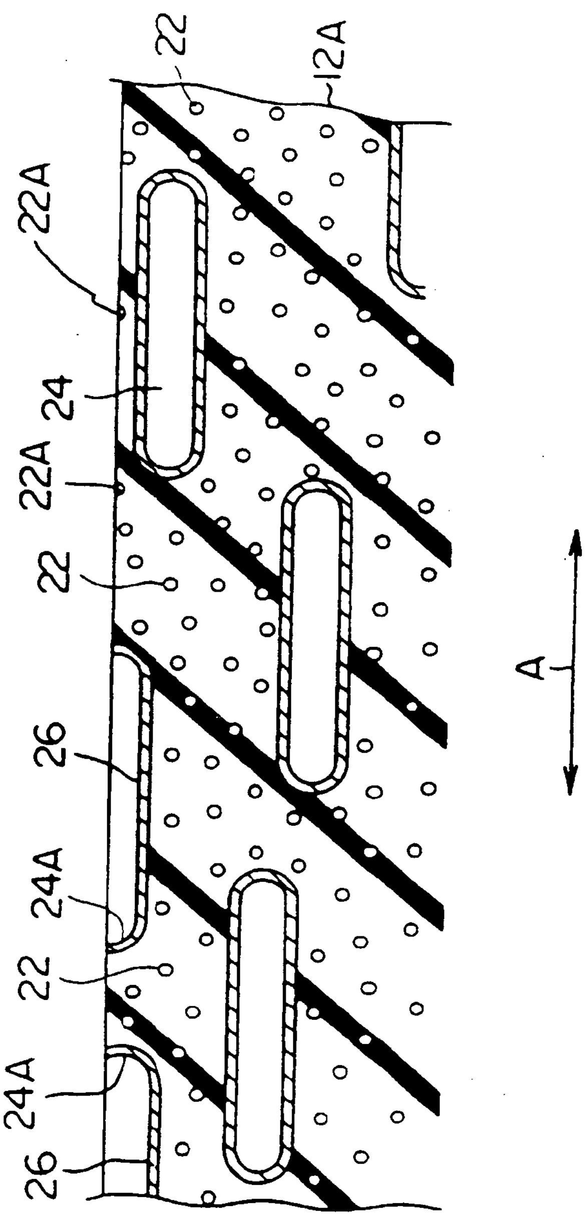


FIG. 11

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(54) **Pneumatic tyre**

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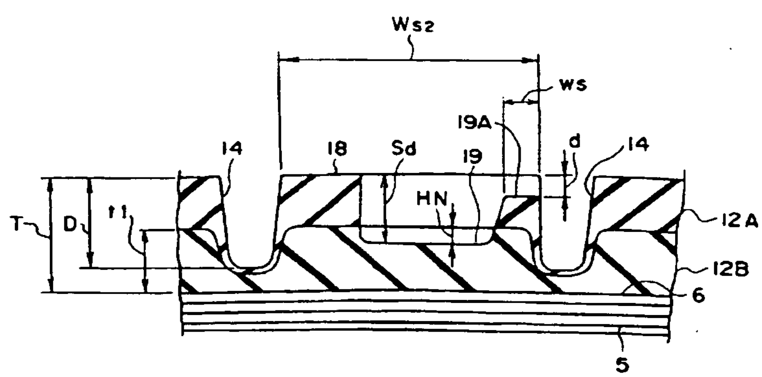
FIG. 3



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